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DEVELOPMENT OF A HYBRID RADAR LANDMASS SIMULATOR: ENGINEERING REPORT NR. 4 (U)

PENNSYLVANIA RESEARCH ASSOCIATES, INC.
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The present report is the final report under this contract. It summarizes the system design presented in previous reports. In addition, it describes the preparation of the culture data for the simulator. The data was digitized from maps and then joined together by means of a computer program. Finally some experiments on region size to determine the adequacy of PRA methods of terrain representation to handle long ranges were performed and the results reported here.

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FOREWORD

Since the development of air-to-ground mapping radar in the 1940's, a need for radar-simulator training devices has existed. This need has been met, until only recently, by analog/optical systems in which aerial photographs are scanned optically to simulate an actual scanning radar. The photographic transparencies, however, are expensive and difficult to update, their resolution has a low practical limit, and the associated hardware is generally unwieldy. The Naval Training Device Center (NAVTRADEVCEN) has long been actively engaged in research into digital radar landmass simulation.

It has long been recognized that the radar data base represented by transparencies could be stored and handled digitally, precluding the problems mentioned above. However, speed and cost constraints of available digital hardware have, in the past, prevented an all-digital approach to radar simulation.

This report describes work done by Pennsylvania Research Associates, Inc., for NAVTRADEVCEN toward developing a hybrid radar landmass simulator. This simulator combines the powerful data-handling capabilities of a general-purpose digital computer with special-purpose hybrid hardware to produce a simulated radar image. The objective here is a flexible research tool which can be used to investigate various approaches to radar simulation.

Alexander J. Grant
Project Engineer
Naval Training Device Center

The findings in this report are not to be construed as an official Department of the Navy position.

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DEVELOPMENT OF A HYBRID RADAR LANDMASS SIMULATOR: ENGINEERING REPORT NR. 4 (U)

I. INTRODUCTION

This document is the final report under contract N61339-68-C-0155 presenting the results of the work at Pennsylvania Research Associates Inc. (PRA) on the effort toward developing a laboratory model radar landmass simulator at Naval Training Device Center (NTDC). This is a continuation of work begun in 1961 to develop digital computing techniques for real-time simulation of the display afforded by a ground-mapping radar. The immediately preceding effort (Contract N61339-1824) demonstrated in non-real-time the techniques to be used in a technically and economically feasible simulator (Ref. 1). Current work will lead to a real-time laboratory model of this radar landmass simulator. The simulator will use a general-purpose digital computer supplemented by a special-purpose hybrid equipment.

The work at NTDC is divided into four phases. The Phase 1 goal is equipment that presents a static display of culture data. The Phase 2 goal is the display of culture data that changes in real time with the motion of the simulated aircraft. The Phase 3 goal is to incorporate terrain effects. Finally, Phase 4 will include special effects such as culture height (i.e., towers showing when their bases are shadowed), multi-level phenomena (i.e., caves, areas under bridges, etc.), variable beamwidths, and variable pulse duration.

PRA's work under the present contract has made contributions to Phases 1, 2, and 3. In addition, simulation experiments using the programs developed under the preceding contract (N61339-1824) were performed. The work is divided as follows:

Phase 1 -- Determine the size and shape of geometric forms to be used in testing the Phase 1 system, and prepare the test plan and test criteria for the Phase 1 system.

Phase 2 -- Perform the overall Phase 2 design (hardware and software) based on use of a scan converter as the major component of the CFG. Determine how to implement specularity, and prepare culture data for the system thus designed.

Phase 3 -- Perform the overall Phase 3 design (hardware and software) based on a polynomial approximation to represent compressed data for expansion by the TFG.

Experiments - Test the adequacy of the polynomial approximation for representing terrain with lower resolution, to provide for simulation of longer radar ranges with the same hardware and software.

Three previous reports have been written covering the above work. These reports are subtitled Engineering Report Nr. 1, Nr. 2, and Nr. 3. (Refs. 2, 3, and 4 respectively.) This report is subtitled Engineering Report Nr. 4. In concept, reports numbers 1, 2, and 3 are primarily concerned with the work on Phases 1, 2, and 3 respectively. Since the Phase 2 and Phase 3 systems were designed together, it was necessary that the reports not be confined to one of the individual phases but rather contain a certain amount of overlap. Table 1 relates the reports to the tasks.

This document summarizes the system design and reports on two tasks not previously described -- the preparation of culture data and the experiments. Section II summarizes the system design. Section III reports on

the data preparation, and Section IV reports on the experiments. Table 2 tabulates the simulation capabilities that are being implemented.

The aircraft turn rate is half of the value previously allowed; it represents a more realistic limit for simulation of a Mach 3 vehicle, and it eases the disk-to-core data transfer requirement. Other numbers given in Table 2 have been adjusted slightly from previous reports to provide consistency between terrain and culture data in digital form, and to be more specific in this report.

TABLE 1 -- RELATION BETWEEN REPORTS AND TASKS

TASK	ENGINEERING REPORT Nr. 1	No. 2	Nr. 3	Nr. 4
Phase 1 (static culture display)				
geometric forms	X			
test criteria	X			
Phase 2 (dynamic culture display)				
system design		X		
specularity		X	X	
data preparation				X
Phase 3 (culture plus terrain)				
system design		X	X	
Experiments on region size				X

TABLE 2 -- LABORATORY RADAR LANDMASS SIMULATOR CAPABILITIES

DIGITAL MAP

TERRAIN REGION SIZE ________ 5,000 ft. square
(Based on polynomial approximation to region containing 24 x 24 raw data points on mesh of 0.01 inch overlaid on 1:250,000 scale map)

CULTURE DATA RESOLUTION ________ 1/32 region (156.25 ft)

PROBLEM AREA ________ 1 deg lat. x 6 deg long. (approx. 60 mi x 270 mi)

SIMULATOR CALCULATION

RESOLVABLE POINTS ________ 832 x 832

DISPLAYABLE REGIONS ________ 26 x 26

AZIMUTH SWEEP SPACING ________ 0.2 deg.

AZIMUTH SCAN RATE ________ 60 deg/sec

(Azimuth sweep spacing and azimuth scan rate: may be changed for synchronization with computer program timing)

FINAL DISPLAY

RANGE, mi	0-20	0-20	0-70	0-70	selectable
AZIMUTH, deg	± 22.5	± 60	± 22.5	± 60	selectable
GROUND RESOLUTION, ft	156.25	312.5	625	1,250	resulting
SCAN DURATION, sec	0.75	2.0	0.75	2.0	resulting

(Plus pause of approx. 1 sec to erase and prime scan converter tube)

AIRCRAFT FLIGHT

SPEED ________ VARIABLE 0 - ½ region/scan (Approx. 0 - Mach 3)

TURN RATE ________ VARIABLE ± 3 deg/sec

ALTITUDE ________
CLIMB/DIVE RATE ________
0 - ∞ subject to scale factors and limits to be determined

II. SUMMARY OF SYSTEM DESIGN

A radar picture is a display of intensity as a function of azimuth and slant range. The varying intensity comes from three factors: terrain slope, shadow, and reflectance. The terrain slope and shadow are derived from the terrain height. Reflectance is determined by the presence or absence of cultural features. "Cultural features" are man-made objects such as cities, railroads, etc. and certain natural features such as rivers and lakes. The radar landmass simulator produces such a display.

As described in previous reports (Refs. 1, 2, 3, and 4) the technique relies on digital storage of terrain and culture data, with apportionment of the calculations between digital and analog equipment. In general the stored data is used to calculate height and reflectance profiles, corresponding to cross-sections through the terrain in a radial direction from the radar, at successive increments of azimuth.

Data is sent to special-purpose equipment which generates the two profiles. The reflectance profile is generated by reading from a culture map which has been written on a scan converter. The terrain height profile is generated using Lagrange polynomials in hybrid equipment.

The computer acts as a intermediary between the data base and the profile generation equipment. The operation has two cycles. during one cycle terrain data is being entered into the computer while culture data drives the culture function generator (CFG); during the other cycle culture data is being entered into the computer while terrain data drives the terrain function generator (TFG). During this latter cycle the reflectance profile is read from the CFG memory in synchronization with the terrain profile generation. These two analog signals are combined to produce the radar display.

The three phases of the laboratory model radar landmass simulator development lead directly to the building of a modular system. The Phase 1 system is built; the Phase 2 system is being added to the Phase 1 system; the Phase 3 system will be added to the Phase 2 system. The Phase 1 system consists of special-purpose equipment to display a static picture consisting of only culture data. The Phase 2 system adds a general-purpose digital computer to produce a moving culture picture. The Phase 3 system adds more special-purpose equipment and computer programs to produce terrain height and shadow effects.

Fig. 1 shows the equipment configuration. This equipment can be divided into common hardware, Phase 2 hardware, and Phase 3 hardware as follows:

COMMON HARDWARE

SIGMA 7 general-purpose digital computer
Sweep generator
Display hardware
Control switches

PHASE 2 HARDWARE

Culture function generator

PHASE 3 HARDWARE

Terrain function generator
Lambert's law computer
Shadow computer

The computer programs are divided into five parts called tasks. Each task performs an individual function. Each function, however, can be thought of a being performed at the same time; tasks are not subroutines. There is a control program (the monitor program of Report Nr. 2) which givescontrol to the various programs as appropriate.

Fig. 2 gives first-level flowchart of the Phase 2 system's programs. Each task is shown as one of a series of parallel programs, all given control by the control program. The tasks are named MISCON, CFCONT, CFPREP, TFCONT, and TFPREP. Those programs whose names begin with TF work on the terrain function generator's data*; those whose names begin with CF work on the culture function generator's data. Those whose names end in CONT send data to the generators; those whose names end in PREP prepare data during the previous cycle. Therefore during one cycle CFCONT and TFPREP are working, and during the other cycle TFCONT and CFPREP are working. MISCON works on demand during both cycles. Thus during each cycle the SIGMA-7 is executing two tasks, and the other two tasks are idle; one task is doing an appreciable amount of interaction with the rest of the system, and the other is not. The interacting task (the CONT task) is called the foreground task and has a higher priority than the other task (the PREP task) which is called the background task.

For a completely Phase 2 oriented system the multiprogramming may appear to require more complex programming. However, this approach to software design permits addition of the Phase 3 system without any change to the Phase 2 system. All interactions between the programs are handled through the control program. Therefore additional programs merely require additional parameters and tables within the control program. The Phase 3 system is made from a Phase 2 system by adding the TFPREP task and the rest of the TFCONT.

*Therefore, the TF programs are part of the Phase 3 portion of the system. The flowchart of Fig. 2 does not give TFPREP, and it shows only that portion of the TFCONT program necessary for the operation of a Phase 2 system.

III. PREPARATION OF CULTURE DATA TAPES

The culture data tapes contain the cultural information necessary for the simulation effort. This data was prepared from maps of the area over which the simulated aircraft is going to fly. The location and, in some cases, the outline of the culture features is obtained from the maps by means of a machine known as a "graphic digitizer". The tape is similar in format to digitizer output except that the data is in a unified coordinate system and the maps are paneled*.

A. Procedure

The procedure used to prepare the tapes is as follows:

(1) The maps were studied and the appropriate cultural features were located and identified for ease in digitizing.

(2) The digitizer was used to locate the point features and outline those features requiring outlines. Each feature was written as an individual record. Each record has a code identifying the type of feature. These codes were retained in final output and are discussed below. Each time a new map was digitized the corners of the map were digitized along with the latitude and longitude of the corners. (This information is used in the conversion program of Fig. 5.)

*Paneling is the term used in the cartographic industry to describe joining of two adjacent charts in a common coordinate system to form a single chart.

(3) The raw output from the digitizer was then converted onto cards for easy updating. Standard utility packages associated with the computer were used.

(4) The data was converted into a unified coordinate system and then plotted. There are three maps from which the data was digitized. The output from digitizer is in terms of the position of the features on the table associated with digitizer. Thus, two conversions are necessary: the coordinates must be converted to a unified set of coordinates relative to some appropriate point on the simulated area of the world, and secondly, since the maps are not rectangles, the coordinates must be rotated appropirately. A flowchart of this program is given in Fig. 5.

(5) The plotted output is now compared with the original maps to check for any possible errors. Errors are corrected manually by keypunching new cards and placing these cards in the data.

(6) The program which produces the plots also produces the final output tape. After all corrections have been made, the final output tape is produced. Fig. 3 gives plots of the final data.

B. Source Data Used

The problem area for which data was prepared is bounded by $80^{o}W$ and $74^{o}W$ on the East and West respectively and $42^{o}N$ and $41^{o}N$ on the

North and South respectively. This is approximately 270 × 60 nautical miles. This area is represented by three USGS 1:250,000 scale maps titled Warren, Williamsport, and Scranton (Refs. 5, 6, and 7). These maps were the primary source of data, and the actual digitizing was done from them.

USGS also publishes other maps of the same area. One series is to a scale of 1:62,500 representing 15' × 15'. Another is to a scale of 1:24,000 representing 7.5' × 7.5'. The 1:62,500 maps do not represent a complete set; therefore, 1:24,000 maps were obtained to fill in the holes. These maps were used as a guide in the planning stage, and to provide extra detail for the digitizer operator where necessary. The actual digitizing, however, was done from the 1:250,000 scale maps.

U. S. Air Target Charts, Series 200 (Refs. 8 and 9) were also used in the planning stage to determine which features are of radar significance. No digitizing was done from these maps; they served as keys to the 1:250,000 maps.

The digitizer which was used has a resolution of 0.0001 meters. (1/10 of a millimeter). Therefore an incremental unit on the digitizer measure represents 25 meters. The operator, however, is not accurate to a 10th of a millimeter; she is accurate to approximately 2/10ths of a millimeter. Thus the digitized data is within 50 meters of its actual location. Within the actual system the data will be stored in increments known as dots. The size of this dot is approximately 150 feet, which is approximately 50 meters. Therefore the digitized data is of the approximately same accuracy as the simulator is being designed to display.

C. Format of the Data Tapes

The data tapes consist of a series of 80-character records. One or more records are associated with each cultural feature. A cultural feature begins with a "C" in the first position of the record, followed

by seven spaces, followed by a feature code, followed by a coordinate count*, and followed by one or more coordinate points. The number of coordinate points may be sufficiently large that subsequent records are necessary to contain them. If this is the case, the subsequent records will merely contain coordinate points with no "C" in column 1. Table 2 indicates the cultural features and the associated codes. Fig. 4 shows the data format.

The coordinates are stored as 8 characters including a decimal point and two digits to the right of the decimal point. The coordinates are nautical miles east and north from 41° 00'N, 80° 00'W. The longitude line 80° 00'W is the Y axis; a line perpindicular in the plane to the Y axis through 41° 00'N latitude at 80° 00'W is the X axis.

For example the data records:

C		3	2	68.02	52.20						
C		2	4	81.60	48.34	81.64	48.22				
C		7	24	69.52	1.03	69.53	1.11	69.66	1.02	69.69	0.9[illegible]
	69.91		0.90	69.76	0.70	69.56	0.69	69.66	0.71	69.50	0.7[illegible]
	69.56		0.87	69.52	0.88	69.52	1.03				

indicate that there is a fire (or radio) tower located at the indicated coordinates and two coordinates are given. There is a drive-in movie located at the indicated coordinates and four coordinates are given. Finally there is a city whose outline is at the indicated coordinates and twenty-four coordinates are given. Fig. 6 is a plot of the above data.

*Note that each coordinate point contains two coordinates. Therefore for a single point the coordinate count is 2.

TABLE 3 -- LIST OF CULTURAL FEATURE TYPES

Feature Code	Type	Note
1	Power Line Towers	1
2	Drive-in Movies	2
3	Fire and Radio Towers	3
41	Large Rivers (water on left)	4
42	Large Rivers (water on right)	4
5	Railroad Yards	5
6	Dams	2
7	Towns and Cities	5
8	Cemeteries	3
9	Major Roads	4
10	Airport	5
11	Big Isolated Buildings	3
12	Marshes	5
13	Lakes	5
14	Islands	5
15	Railroad Tracks	4
16	Small Rivers and Creeks	4
17	Bright City Areas	5

NOTES:

1. A string of single points with each point indicating an individual tower.
2. Two points indicating the endpoints with the parking lot or water on the right.
3. A single point.
4. A string of points indicating line segments.
5. A closed polygon with the feature on the right.

IV. EXPERIMENTS USING LARGER REGIONS

A. Purpose of the Experiments

As has been stated in Section II of this report, terrain is to be stored in the Phase 3 system in Lagrange polynomial coefficients. Experiments were carried out under Contract N61339-1824 to show that this method of data representation was adequate for generating radar pictures of the terrain. The experiments consisted of a non-real-time simulation (by a computer program on a CDC 6600 computer) of the recommended real-time simulation equipment (computer plus special-purpose digital and analog equipment).

In those experiments the Lagrange polynomial region size was 3,800 feet by 3,800 feet. The overall ro t-mean-square (RMS) height error was 30 feet, slightly under 2% of the overall height range in the area tested (the range of heights was 400 to 2,200 feet). Fig. 7, taken from the final repor of that contract, is a topographic map of the demonstration area. Fig. 10a, also taken from that report, shows one of the simulated radar pictures generated by this program. The maximum range on this picture is approximately thirty nautical miles.

The degree of feature resolution shown in this picture is not necessary when a larger range (80 nautical miles) say is shown on the radar display. For such a display it is planned to use a larger Lagrange polynomial region size.

Using a larger region size means that less data must be transferred to the Height Function Generator unit during a radar sweep. New data is transferred whenever the simulated sweep crosses a region boundary. Thus, for example, if the region size is doubled, the amount of transferred data remains constant.

The use of a larger region naturally means a worsening of the resolution and accuracy of the terrain representation. However, the radar display covers a larger area on the same size screen and hence less resolution and accuracy are required.

Note, for example, that the planned Phase 3 system is to use a 10.000 foot region to store terrain data when a 70 nautical mile range is shown. On a seven inch display tube, a region corresponds to approximately 0.15 inches. The polynomial technique is capable of generating up to a hill per region (i.e., separate hills in adjacent regions) and thus should provide sufficient resolution. Also, computer experiments carried out under contract N61339-1824 indicated that the RMS error is proportionate to the region size over a wide range of region sizes and that thus the accuracy would also be satisfactory.

However, only the 3,800 foot region was used in the computer simulation program. The purpose of the present experiments was to use the simulation program on the CDC 6600 to generate a radar picture using a larger region to demonstrate that such a picture would be satisfactory.

There was also the question as to whether or not there would be an undesirable pattern in the displayed picture due to an undulation (or low-pass filtering) effect that was suspected as possibly causing trouble. (This is discussed later in this section of the report).

B. Problems in Conducting the Experiment

It was originally intended that the computer runs be carried out on the same CDC 6600 that had been used under the earlier contract (Contract N61339-1824). This computer was no longer available and, as such, it became necessary to run the programs on a different CDC 6600. This computer had a somewhat different operating system and a smaller

memory and thus it was necessary to make some adjustments to the program. The major functional change involved changing the routine that created the Lagrange polynomial coefficients so that it uses a smaller array of height data. (Only every sixth height in the original input height grid is used).

Another result of this switching of computers was that it was not possible to optimize some of the display parameters in the program, e.g., corresponding to the contrast and brightness controls on a radar. However, this optimization is not necessary to prove the result.

C. Exploring the Undulation Effect on Range Regions

The simulated radar picture to be generated was essentially that shown in Fig. 10a; this involves looking towards Williamsport (See Fig. 7) from point A on Figure 7. The region size was changed from 3,800 feet to 7,600 feet.

The computer output was unsatisfactory in that culture data appeared overlaid at an erroneous scale. Thus the full picture is not included in the report. However, the results were sufficient to show the presence of the undulation effect mentioned above. (See Fig. 8.) Note that there appears to be a grid effect corresponding to the region size.

The reason for this effect is now understood. It is inherent in the particular method used to generate the polynomial coefficients and is not related to the capability of the Lagrange polynomial method, which has already been shown (in the earlier experiments) to give good pictures without any grid effect.

The Lagrange polynomial technique has been described in earlier reports (in particular, Engineering Report 3 of the present

contract). It will be remembered that the coefficients associated with a particular region corner are used in all four regions that come together at that corner. Thus there is an interaction among the polynomial coefficients that runs throughout the full area covered. (For example: Corners A and B both are used to generate the terrain in Region 1; B and C are used in Region 2; C and D in Region 3; etc.) The least square method used to compute the coefficients is affected by this interaction.

The actual method is described in the Final Report of Contract N61339-1824. In the present report a one dimensional analogue will be used to illustrate the undulation effect.

Consider Fig. 9. Line 1 shows the actual height profile running across several region boundaries. The problem is to determine polynomial coefficients at the boundaries A, B, C, ... G, to give a good fit. Remember that the height at any point is based on the coefficients on the surrounding corners.

The least square method used here considers two regions simultaneously (four in the two dimensional case). This gives a fit as shown in line 2. We then throw away the computed coefficient at point C, and optimize over regions BC and CD using the already determined B as a constraint and computing C and D. This gives us the fit shown in line 3.

Next this step is repeated for regions CD and DE, with C as an input constraint. Note that there is a remembered erroneous slope from each earlier fit that propagates into the new least square fit. Line 6 shows a decaying ripple with a cycle period of two regions following along. This is of low amplitude but even a low hill causes an undesired radar shadow. (Again see Fig. 8.)

Obviously, the effect would disappear in this case if the interaction had been from right to left in generating the coefficients. Or, it could be removed by a prefiltering of the height data or by using a better method for least square fitting.

D. Adjusting the Program

It was desired that the polynomial coefficient generation program be revised so that the undulation effect would disappear. Several techniques were possible; the chosen one was selected as being easiest to implement as a modification to the present program.

Again the adjustment is discussed in terms of its one dimensional equivalent. Consider again Fig. 9. The difficulty here was that the effect of the hill at B propagated on to many other regions. For example in line 5, the upward slope at D forced a downward slope at E. The obvious solution is to remove the effect of the propagated slope at D when E is computed.

The selected method still optimizes the values at E and F, taking D into account. However, instead of using the computed value of coefficients at D, an estimated set is used based upon the height values near the D corner. The RMS error goes up but the undulation effect disappears.

In the two dimensional actual case, the RMS error for the run became 200 feet, 11% of the full height variation. However, the results were satisfactory in the portrayal of gross terrain shape.

E. Results of the Adjusted Experiment

Fig.10b shows the results of the computer run with the adjusted polynomial coefficients. It is shown next to the results

with the smaller region size (Fig. 10a). As stated above, the brightness and contrast have not been adjusted correctly in the program output to give the best display, so a direct comparison of the fine detail is difficult to make.

Nevertheless the pertinent ridges of hills appear identical in the two pictures. Note also that the individual peaks generally correspond: note in particular the comparisons of hills in Ridge 4.

This picture in the vertical direction covers approximately thirty miles. Thus, it appears magnified in this picture over its actual appearance on a radar scope.

Therefore, the experiment has demonstrated that the use of a larger region for terrain fitting is practical; however the method for generating the coefficients must be revised from that used earlier. Since this is a procedure involved with digital simulator map preparation, it does not affect the real-time aspects of performing the simulation.

V. REFERENCES

1. Pennsylvania Research Associates Inc., Demonstration of Digital Radar Landmass Simulation Techniques, U. S. Naval Training Device Center, Tech. Rpt. 1824-1, October 1967; AD 622 407.
2. Pennsylvania Research Associates Inc., Development of a Hybrid Radar Landmass Simulator: Engineering Report Nr. 1 (U), U. S. Naval Training Device Center, Tech. Rpt. 68-C-0155-1, July 1968.
3. Pennsylvania Research Associates Inc., Development of a Hybrid Radar Landmass Simulator: Engineering Report Nr. 2 (U), Tech. Rpt. 68-C-0155-2, November 1968.
4. Pennsylvania Research Associates Inc., Development of a Hybrid Radar Landmass Simulator: Engineering Report Nr. 3 (U), U. S. Naval Training Device Center, Tech. Rpt. 68-C-0155-3, January 1969.
5. USGS 1:250,000 map WARREN, Pennsylvania.
6. USGS 1:250,000 map WILLIAMSPORT, Pennsylvania.
7. USGS 1:250,000 map SCRANTON, Pennsylvania.
8. United States Air Force Air Target Charts Series 200 (U): 0309 20 HL, 0310 11AL, 0310 16AL, and 0309 15AL.
9. United States Air Force Air Target Charts Series 200 (U): SO 309-14AL - 1st Ed. 8/61, SO 309-19AL - 1st. Ed. 8/60, SO 310-12AL - 1st Ed. 7/61, SO 310-17AL - 1st Ed. 3/61.

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Descriptors

CULTURAL FEATURES
HYBRID
LANDMASS
PENNA. RESEARCH ASSOCIATES
PROGRAMS
RADAR
REPRESENTATION
SIMULATOR
TERRAIN MODEL

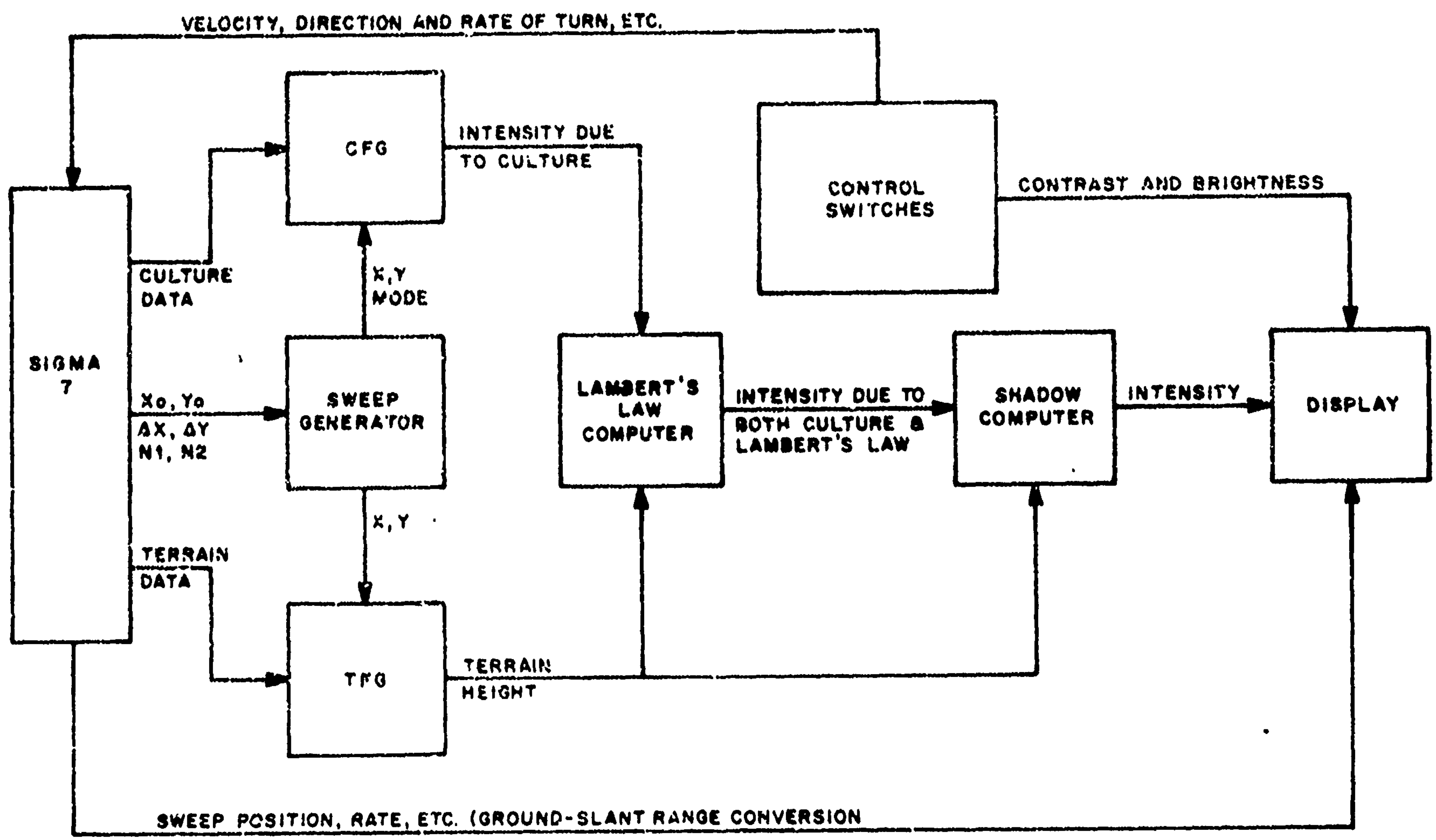


FIG. 1 - HARDWARE CONFIGURATION

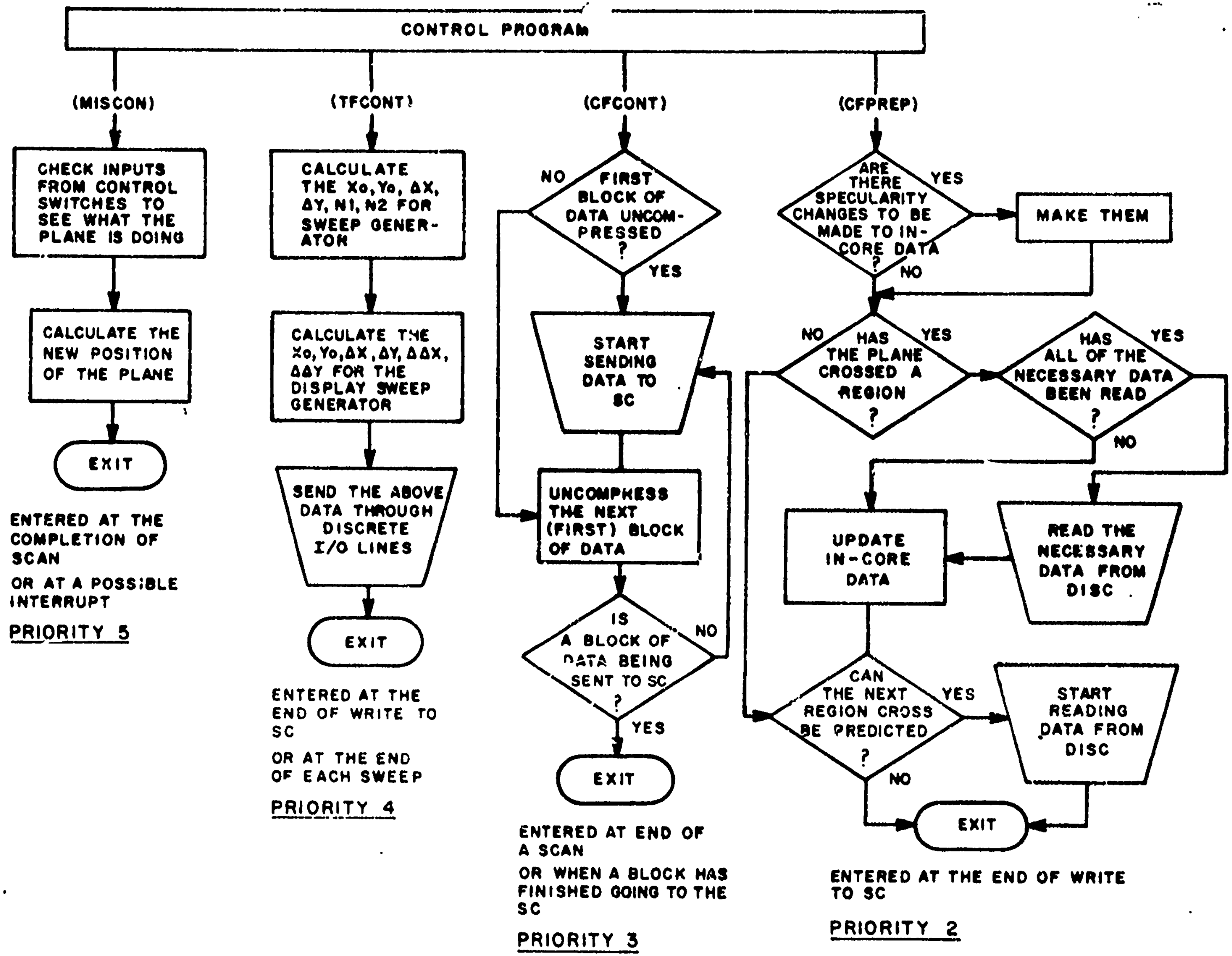


FIG. 2 - MACRO FLOWCHART OF PHASE 2 SYSTEM

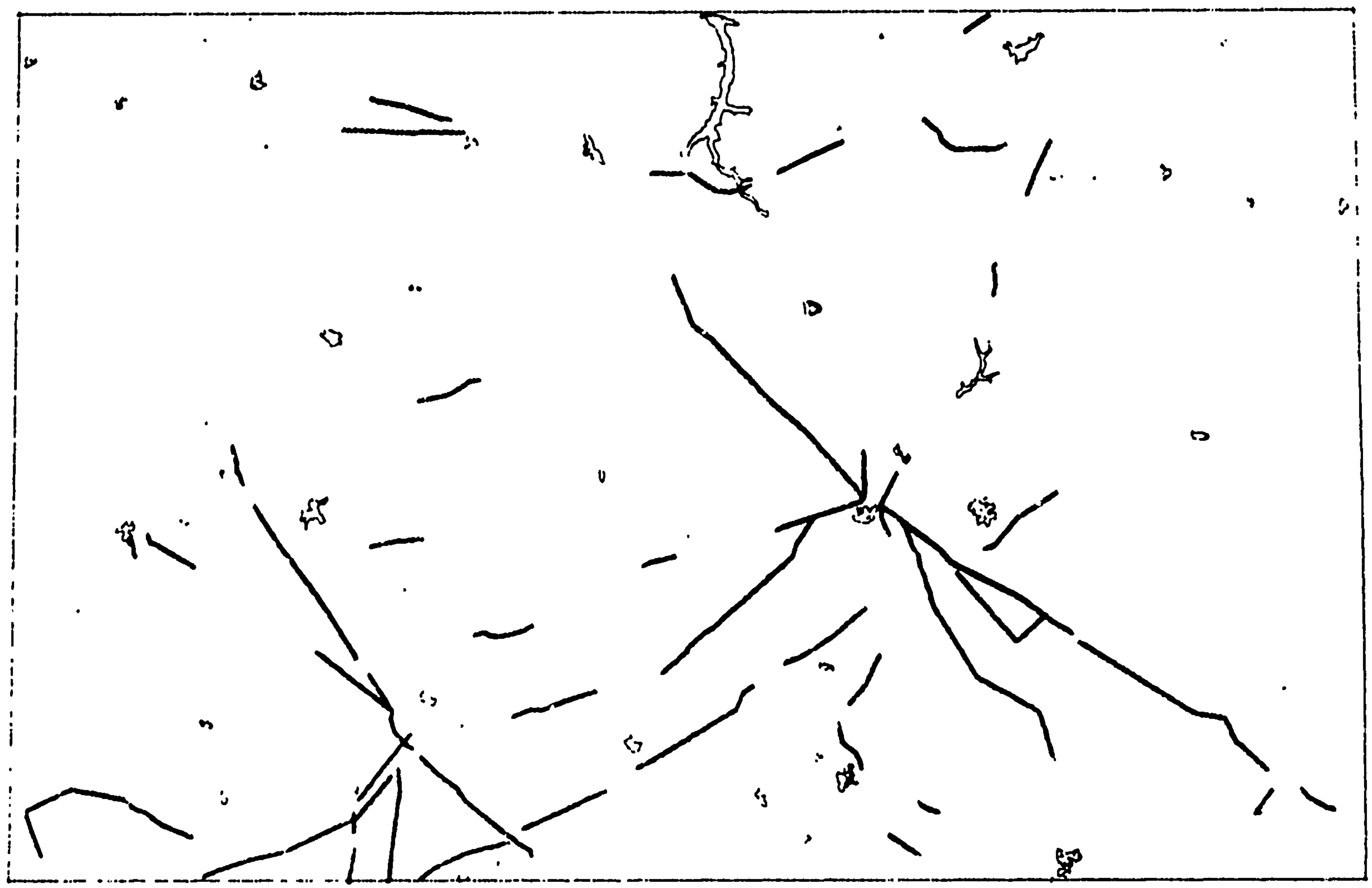


FIG. 3 - PLOT OF CULTURE DATA (SHEET 1 OF 3)

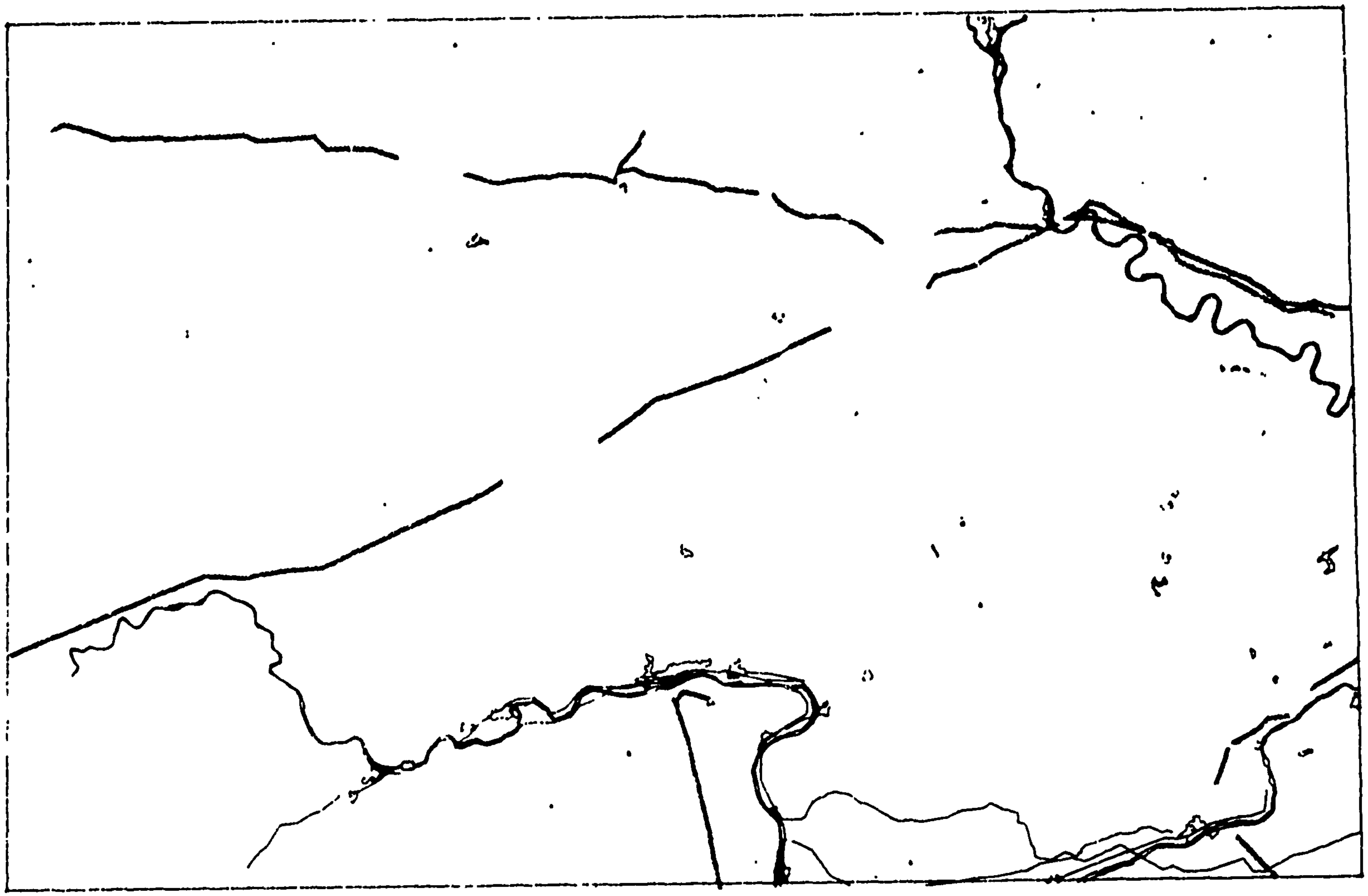


FIG. 3 - PLOT OF CULTURE DATA (SHEET 2 OF 3)

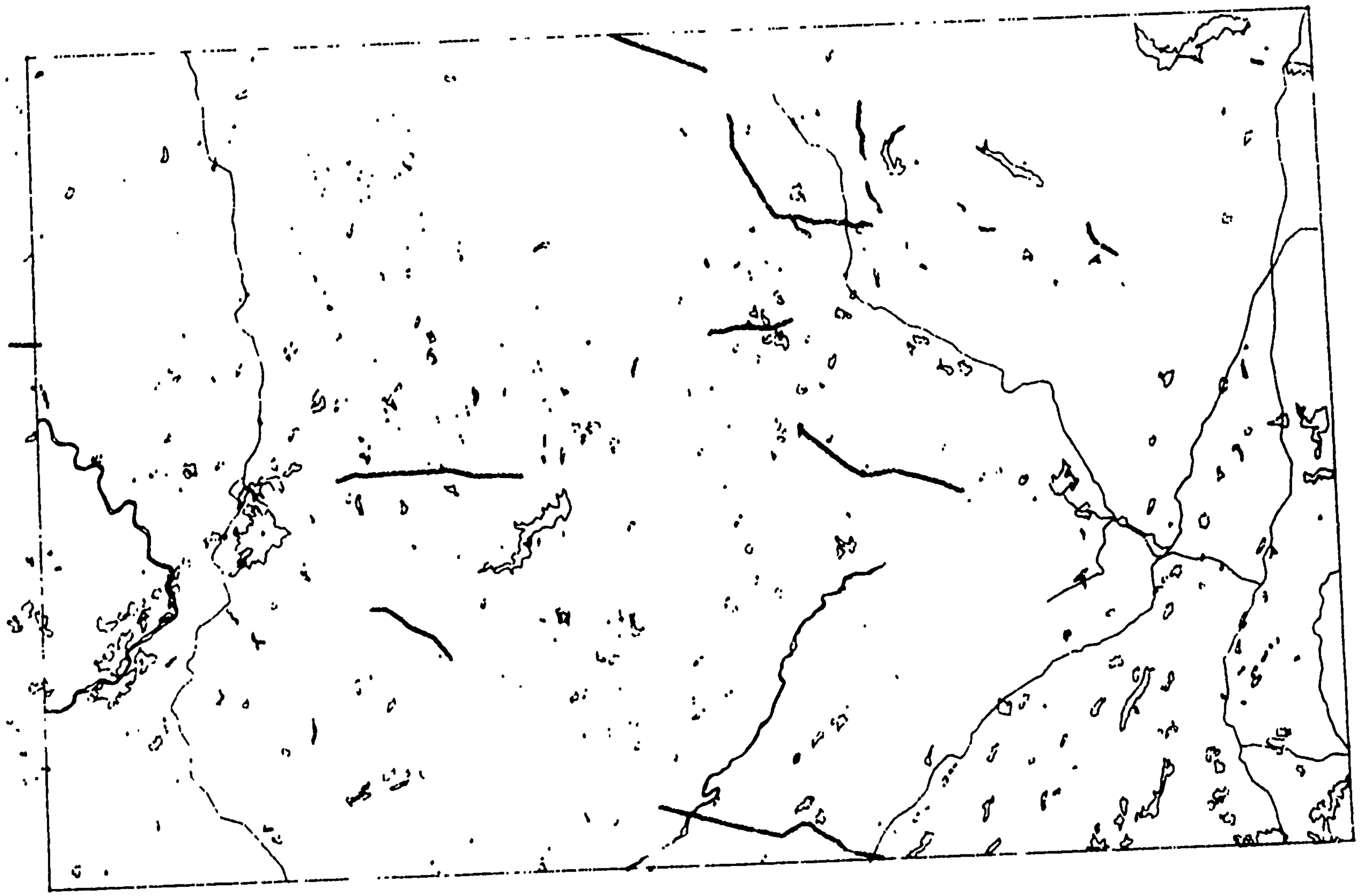
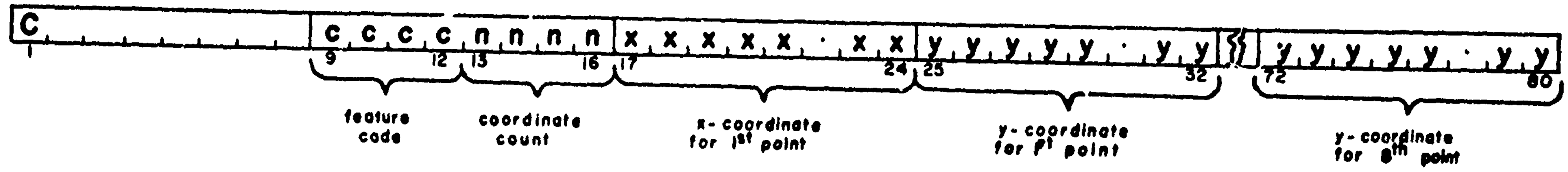
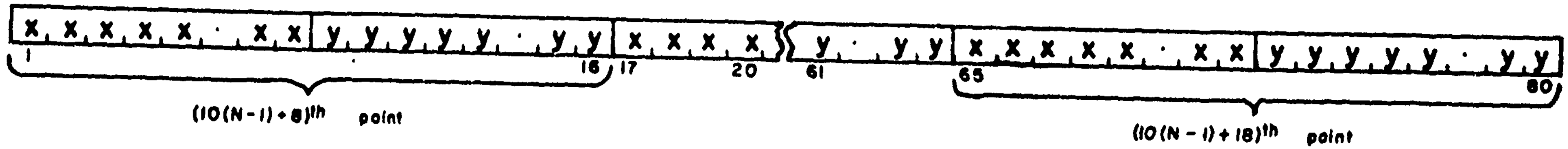


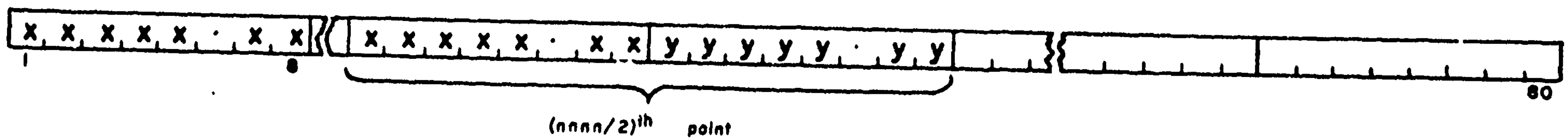
FIG. 3 - PLOT OF CULTURE DATA (SHEET 3 OF 3)



First Record of a Feature

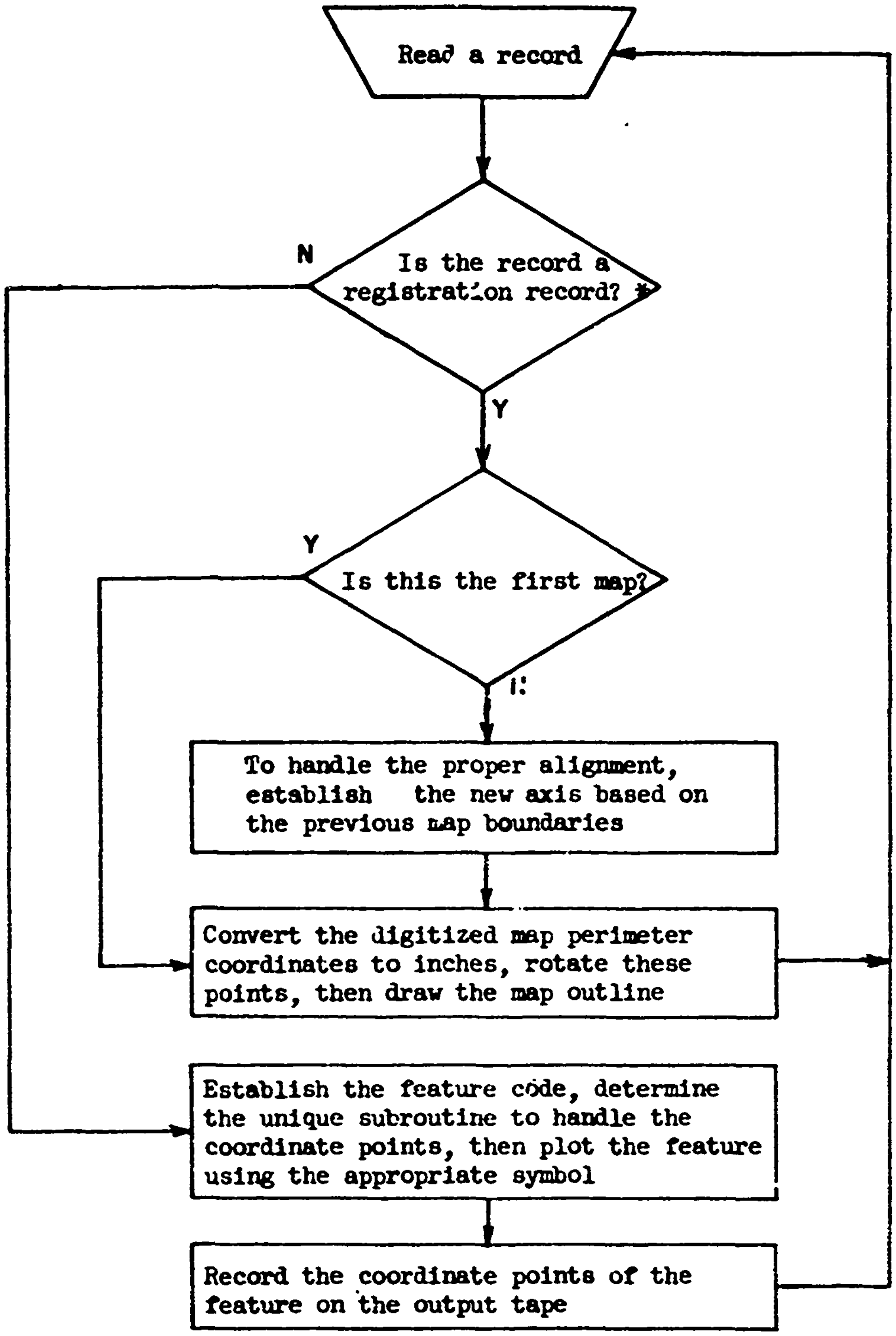


Nth Record of a Feature



Last Record of a Feature

FIG. 4 - DATA FORMAT



* This series of steps determines the type of record. If it is a registration record, the map boundaries are established from the digitized endpoint coordinates. If it is a feature record, the feature type is determined and the feature plotted. Error and end-of-file conditions are also handled here.

FIG. 5 – DATA PREPARATION PROGRAM

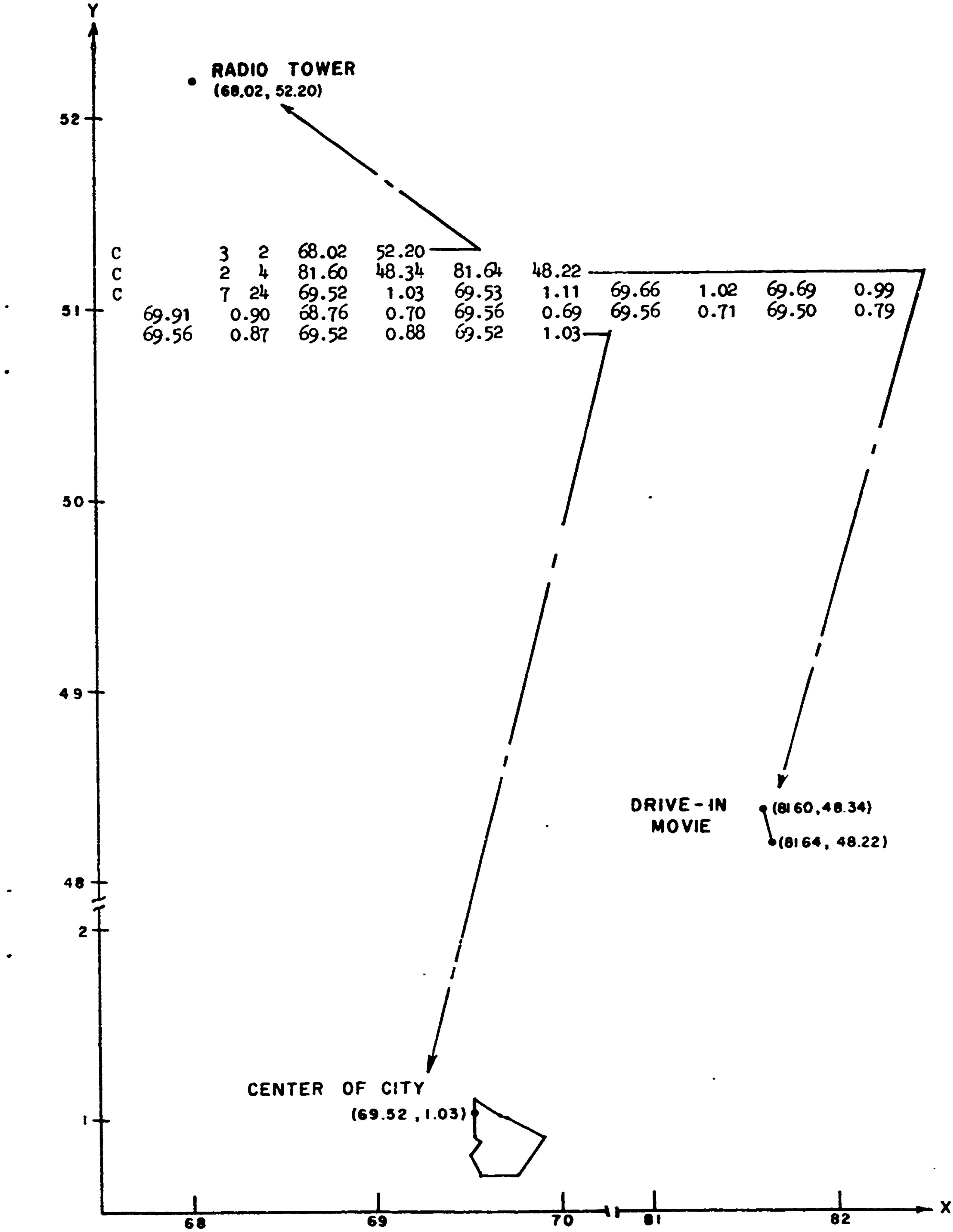


FIG. 6 — EXAMPLE OF CULTURE DATA

FIG. 7– TOPOGRAPHIC MAP OF DEMONSTRATION AREA

FIG. 8— GRID EFFECT DUE TO UNDULATION

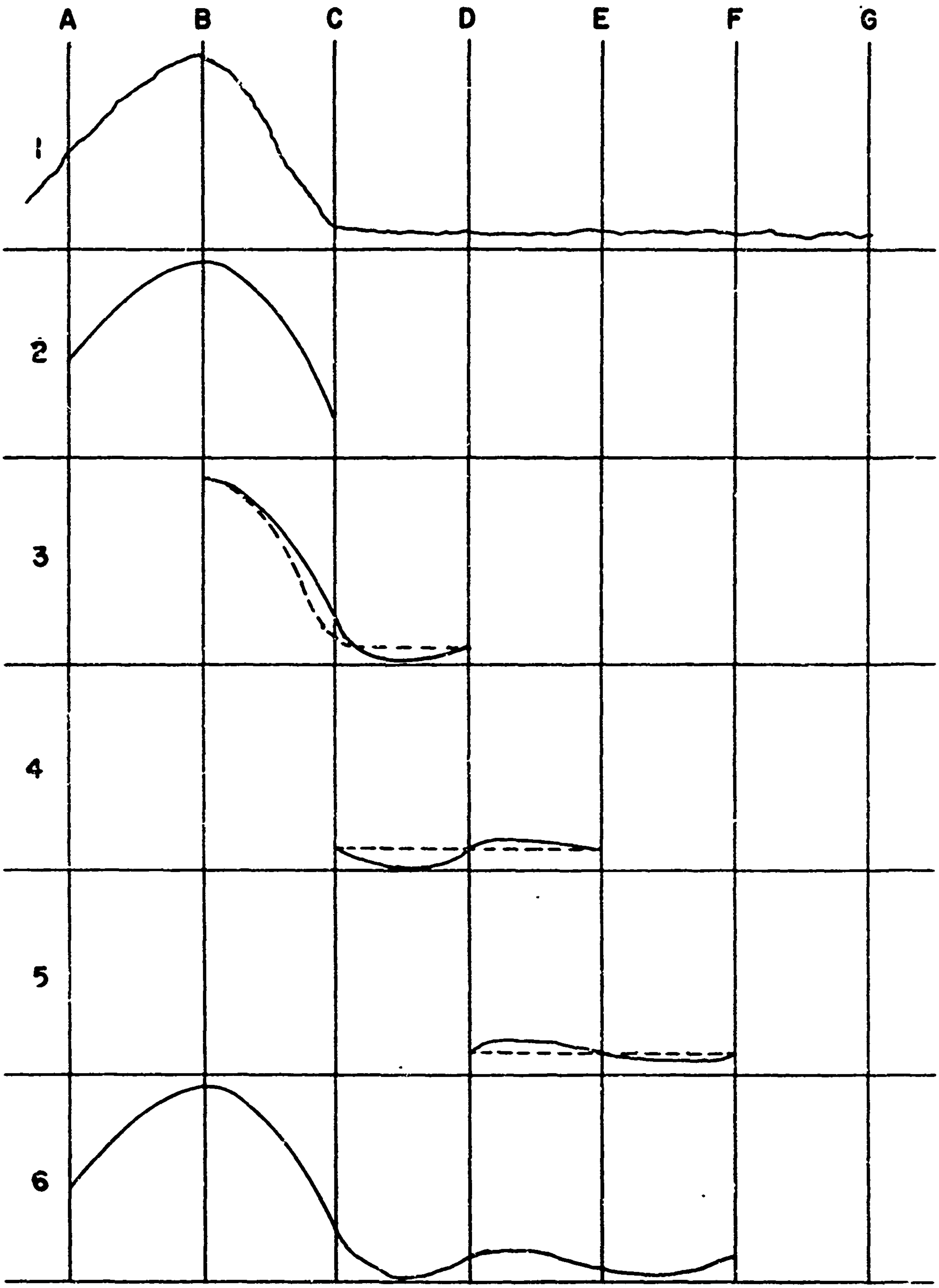
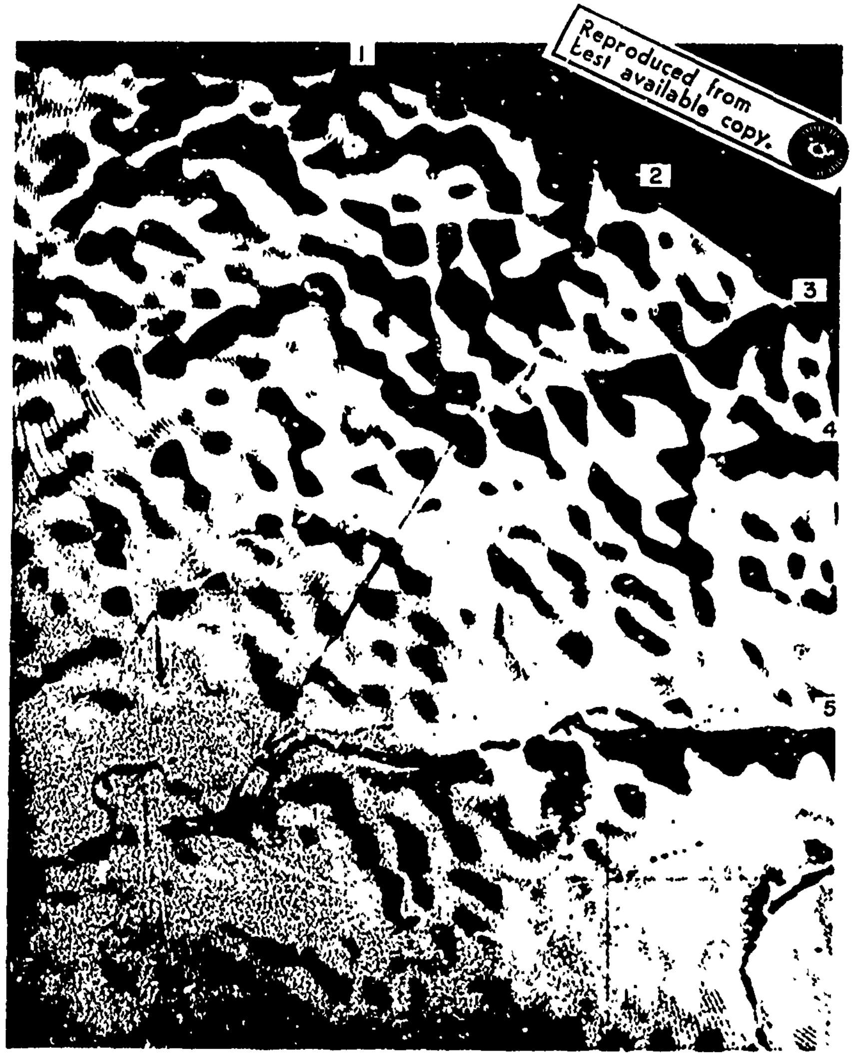


FIG. 9 — UNDULATION EFFECT

a – SMALL REGION



b – LARGE REGION

FIG. 10 – SIMULATED RADAR PICTURES